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MANUAL OF METHODS FOR FISHERIES RESOURCE SURVEY AND APPRAISAL

Part 3 - Standard Methods and Techniques for Demersal Fisheries Resource Surveys

by

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Rome, September 1973

PREPARATION OF THIS DOCUMENT

This publication is one of a series of FAO Manuals in Fishery Science. It has been prepared as part of the programme of the FAO Fishery Data Centre of the Fishery Resources Division, and largely based on the work conducted in providing technical advice to the FAO-executed UNDP field projects on fisheries with survey programmes.

The present provisional version has been reproduced primarily for use in FAO and in FAO field projects, training courses, and for limited distribution to specialists on the basis of whose comments it is planned to publish eventually a revised edition in the official languages of FAO.

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Regional Fisheries Officers
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Field Experts (Resource Surveys)
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Bibliographic entry:

Mackett, D.J. (1973)
FAO Fish.Tech.Pap., (124):38 p.
Manual of methods for fisheries resource survey and appraisal. Part 3 - Standard methods and techniques for demersal fisheries resource surveys

Fisheries resources surveys - methods of appraisal and evaluation. Survey objectives and strategy. Selection of species, area, vessel and gear. Sampling and statistical calculations. Field work - organization. Trawl catch measurement - estimations. General instructions.

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1. PREFACE

The purpose of this manual is to introduce some of the first elements of systems analysis into the conduct and strategy of FAO demersal resource surveys and to illustrate the steps of stratified random sampling as a tool in assessing demersal stocks of fish. To round out the presentation, a number of suggested methods for measuring and recording catches and lengths of fish are also given. Finally a standard form and instructions for recording the results of the survey and for estimating yields is included in the Appendix.

The systems approach is advocated because it is a method which overcomes many of the shortcomings of the more narrowly scoped scientific method which, by the way, can be thought of as a logical sub-set of systems analyses. Systems analysis emphasizes asking the right questions to get the answers that are needed to stimulate an action. The scientific method, on the other hand, emphasizes getting the answer to whatever question - pertinent or not. The systems approach emphasizes the giving of advice while the scientific method emphasizes the gaining of understanding. With these distinctions in mind one comfortably can travel mentally from the systems mode of thinking to the scientific mode and back again. In advocating the systems approach due recognition is given to the value of the scientific method in certain situations. That is why, as one expression of the scientific method, stratified random sampling is suggested for gaining a better understanding of one of the aspects of a survey - the estimation of stock sizes. In many respects this manual was written in the systems mode - the problem was formulated, objectives were set out, information was sought, a draft was written and subjected to the criticisms of a number of individuals; these people applied a set of criteria of satisfaction and found that they either preferred some other version or accepted as adequate what was written. During the process of the second and third drafts the problem changed, new objectives were introduced, more information was gathered and the criteria of critics were altered; finally in systems parlance the system was "frozen" and the final draft was printed.

The author wishes to acknowledge and thank all those who knowingly or not took part in the systems approach by applying their criteria of satisfaction to the various drafts of this manual. The reader should not infer that all the persons deserving of thanks are as yet entirely satisfied with this version of the "system". Thanks are due to N. Abramson, E. Akyüz, D. L. Alverson, C. Berude, L. Boerema, E. Cadima, W. Fischer, J. A. Gulland, K. Isarankura, G. Kesteven, B. Parrish, D. F. S. Raitt, B. Rothschild, and J.-P. Troadec.

2. SURVEY OBJECTIVES AND STRATEGY

2.1 Relationship of resource surveys to investment

Most often the ultimate purpose of fishery resource surveys, conducted by FAO, is to stimulate investment for developing a new fishery or significantly extend an existing fishery. In this context it is important for a survey planner to take into consideration the requirements of potential investors and the best means of communicating the results of the survey to them.

When one considers that an investor can be an individual, a foreign or domestic company, a government, or an international banking institution, it is easily seen that a variety of viewpoints and investment objectives can exist. Furthermore, with a combination of investor types interested in development opposing investment objectives can exist simultaneously. For example, an individual's or company's objective may be to obtain the highest return on its investment in the shortest possible time; a country, taking a broader view, may wish to produce as much protein from the sea as it can over a long period, and in the process help solve a labour problem. On the other hand, an international banking institution may consider among other things the total impact of a developed fishery on the gross national product of a country.

With different investment objectives it can be expected that investors would differ also in the risks they are willing to take and in the scale of investment situations that are of interest to them. In this complex investment environment the project must be able to offer advice to potential investors and recommend a course of action for development to the government.

The project that takes potential investor requirements into consideration during the planning and conduct of the resource survey is increasing its chance of success (i.e., developing a fishery) by being in a position to:

(1) Communicate the right information about the resource to the right investor at the right time.

(2) Recommend a well thought-out plan to obtain the investment for implementing the fishery.

2.2 Survey objectives

As was previously mentioned, the ultimate aim of most FAO resource surveys is to provide facts and information to potential investors who are interested in developing a new fishery or extending an existing fishery. Therefore, the working objectives of the survey must be consistent with the information that is needed to make wise investment decisions. What information is needed?

The information that is needed during the course of a fishery development project can be classified into three stages or phases. Each phase is characterized by the situation of the investor; survey objectives and investor decisions can be related to each phase. Table 2.2.1 sets out a concise and somewhat abbreviated series of stages and related investor questions and survey objectives.

As the survey proceeds it becomes involved with more detailed questions and with explaining more sources of possible variation in the stocks and catch rates. Typical survey objectives that are required in each phase are discussed in the following sections.

2.2.1 First phase objectives

Initially, when very little is known about the resources, the survey will have the simple objectives of answering two questions:

(1) What types of fish are in the area?

(2) What catch rates can be obtained?

Table 2.2.1. Phases of a resource survey

	PHASE I	PHASE II	PHASE III
SITUATION	• Very little known about the resources	• Marketable species are found in the area • Commercial catch rates either obtained or thought feasible • There is investor interest in learning more before investing	• Potential yields at acceptable level • Markets are located • Rate of investment planned • Investments in shore facilities begun • Fishing started or about to start
INVESTOR QUESTIONS TO BE ANSWERED	• Is there a possibility for a commercial venture? • Are the species in the area marketable?	• What is the magnitude of the investment required? • What return on the investment can be expected? • What shore facilities will be required to market the fish? • What are the costs of operating? • Is the supply constant, seasonal or erratic? • How accurate are the estimates; what are the risks? • At what rate should fishing units be employed - slowly, moderately, quickly?	• Does the rate of investment require adjustment • Should fishing tactics be changed to become more cost/efficient? • What adjustments in marketing are requires vis a vis predictions in the variation of availability and abundance? • Do controls on the fishery require changes in marketing, investment or fishing tactics?
OBJECTIVES OF THE SURVEY	• What types of fish are in the area? • What catch rates can be obtained?	• What is the magnitude of the stocks and their potential yields? • How rapidly will catch rates decline under various levels of fishing? • How much effort (no. of boats) is required for optimum exploitation? • What is the seasonal and spatial variation in availability? • What are the oceanographic features associated with fish abundance or behavior? • What fishing methods are most successful?	• Refined and improved estimates of resources magnitude, catch rates, optimum fishing effort • Prediction of variation in abundance or availability • Definition of sub-populations • Measurement of the effects of fishing on the resource • More efficient fishing tactics • Adequate legal controls to protext the resource and ensure economically viable fishery

With the answers to these two questions and with information on the unit operating costs and marketing situation, the potential investor can decide whether or not he should further his interest in a possible commercial venture. In some cases - say the discovery of shrimp beds yielding high catch rates - some investors may decide immediately to begin fishing operations on a moderate scale, and decide later exactly how many fishing units to employ. In other cases the investor may find that the facts warrant further interest, but he desires to have more information on the resources before taking a final decision to invest in the development or expansion of a fishery. An investor in this situation is interested in the magnitude of the resource and its potential yields and the optimum number of vessels or fishing units required. At this point the resource survey must respond to this need for a different kind of information and change its objectives accordingly.

2.2.2 Second phase objectives

A survey that has already met the first two objectives (i.e., a determination of the types of fish in the area and the approximate catch rates that can be achieved) and communicated the information to those who are interested in investment, then enters a second phase with different objectives. During the second phase the survey concentrates on supplying specialized information on the stocks or environment which will influence future practices of investment, vessel operations, or management. The objectives of the investigation are directed toward estimating the size of stocks and their potential yields. The information is intended to provide the facts required for efficient utilization of capital, manpower, and the resource itself. The objectives of the second phase of the resource survey can be set out as:

(1) Estimating the magnitude of the stocks and their potential yields.

(2) Calculating more precise estimates of expected catch rates and especially how these rates can be expected to decline with increasing fishing effort.

(3) Calculating the first estimate of the fishing effort (number of vessels) required for optimum exploitation.

(4) Predicting seasonal and spatial variation in stock distribution and the year-to-year fluctuation in stock abundance or availability which will affect the catch rates or cost of fishing.

(5) Observing and estimating biological and environmental parameters correlated with fish behavioral changes which affect the success of fishing or the abundance of fish.

(6) Collecting information on the fishing techniques and methods that are successful in the local situation.

All of these factors will influence the tactical decisions of investors concerning the rate of investment - such as whether there should be a gradual increase in the number of new fishing units or immediate full-scale investment. The results will also provide information on how quickly or slowly returns on investments will be realized. The estimation of the magnitude of the resource and its potential yield can be helpful in estimating the upper limit on the investment required for ships and shore facilities. The information on how catch rates can be expected to decline and the estimates of fishing effort required for optimum exploitation will lead to more refined estimates of the investments needed, and of the profits to be obtained.

Finally, information on variability of abundance, availability and fish behavior can be evaluated in terms of the fishing tactics that might be required, the operating costs, and the first estimates of the magnitude of the supply problem and its impact on the market. Usually, the estimates provided by a survey in the absence of data from a fishery will not be very precise. However, even rough estimates, say ± 50% of the true values are good guides to the scale of investment and amount of fishing which can be introduced before more serious consideration must be given to preventing over investment. In this case, estimates of how rapidly falling catch rates will decline can contribute to a useful measure of when the prospect of over investment will become a problem.

2.2.3 Third phase objectives

In most cases when the resource survey has provided the information required in the first two phases of operation, an investor already has enough resource information to allow him to take a rational investment decision. Provided that the condition of markets, shore facilities and costs of operations, etc., are satisfactory, a fishery may be started. The resource survey must now turn toward refining and improving the estimates of resource magnitude, catch rates, and optimum fishing effort. The survey must also provide more details on the variations in abundance and availability, and gather more information on fish behavior in relation to environmental factors. However, with a fishery in existence, this stage of investigation can be carried out more efficiently if the catch, effort, and area of fishing data from the fishery are analyzed along with the survey data. As more knowledge is gained from the fishery less general information is required from a research vessel survey. The objectives of the survey then become more and more specialized, and in general the marginal returns on the investment cost of the survey are reduced.

Beyond seeking the refinement of previous estimates, the operating objectives of the survey will depend more on the specific nature of the resources and the state of the fishery. In some cases the delineation of separate stocks of important species may become the most pressing problems and tagging or morphological studies may be carried out. In other cases the survey may need to forecast recruitment based on assessments of year-class strengths or environmental conditions. At this stage many surveys turn toward experimental fishing to explore the utility of various types of gear and fishing tactics to increase the efficiency of the fishery.

2.3 Survey strategy

The strategy for conducting a resource survey is essentially the large-scale planning and direction of the surveys operations. Another element may be added to that definition of strategy, and that is that strategy also includes the way we think about planning and guiding the project to a successful conclusion.

In the previous sections, the purpose and objectives of most resource surveys conducted by FAO were set out and it was implied that the measure of performance of a survey was the timeliness and usefulness of advice needed for fishery investment decisions. Certainly, objectives and performance measures will be elements of the survey strategy, and thinking about the objectives is a logical place to begin, but there are many more things that must be considered in order to develop a good strategy.

Borrowing from Churchman's (1968) discussion of systems, one can conclude that there are five basic considerations that must be kept in mind when planning or directing a resource survey:

(1) The total survey objectives and more specifically the performance measures of the whole survey.

(2) The fixed constraints on the survey: this is the survey's environment (not to be confused with the term environment as used in ecology).

(3) The resources of the survey, e.g., manpower and budget.

(4) The various components of the survey: their activities, goals, and measures of performance.

(5) The management or direction of the survey: how decisions are made to conduct the day-to-day operations.

2.3.1 Objectives as variables

In the previous sections the operational objectives of a survey were discussed in some detail. However, in this section a broader view of the question of defining objectives as part of the strategy of managing the project is discussed.

Stating the real objectives of the survey is no easy matter. Commonly, the stated objectives emphasize the obvious and thereby obscure recognition of the real objectives with the possible consequence of the survey spending its time and money (resources) answering the wrong questions. For example, a scientist who collects, prepares and reads scales from fish may state that his objective is to make as accurate a determination of the total mortality rate as possible. But the real objective is not accuracy but what accuracy is good for: improving the advice given to investors or fishery managers. If one tries to look ahead to the desired outcome, one is in a better position to determine how important the objective really is. In some cases improved accuracy may not be worth the cost, i.e., the sacrifice of other objectives (Churchman, 1968).

It is useful to move from stating objectives of the survey to thinking about measures of performance. As was stated earlier, one measure of performance that we can apply to surveys is the usefulness and timeliness of advice to investors, but as in the case of objectives the "obvious" measures of performance are not often the real ones. Consider that a survey provides timely information and advice to an investor, i.e., the information is available to the investor just before he needs it to help him make his next investment decision. Consider also that as a consequence, his decisions lead to the mechanization of a fishery and that his investment goals were realized. By the stated measure of performance the survey would be considered a success. But would the project also be considered a success if it was known that by mechanizing the fishery a number of artisanal fishermen were without work and had to be cared for with emergency food programs?

Thus, in determining objectives and measures of performance the wise survey director will try to find as many relevant consequences of the survey's activities as he can, and include them in his plan or strategy for conducting the survey. He should be prepared to treat objectives and performance measures as variables and revise his opinion of what these should be in the light of what he learns from the survey operations and from the survey's environment.

2.3.2 The survey's environment or fixed constraints

The environment in which the survey is conducted is the sum total of things and people that are fixed or given concerning the conduct of the survey. The environment determines the constraints within which the survey must operate. For example, if the budget for the survey is fixed or given to it by the sponsor of the survey and if the budget cannot be changed by any activities of the project, then the constraints imposed by the fixed budget are in the survey's environment and must be dealt with. On the other hand, if the survey activities could influence the size of the budget then the process of budget specification is not in the environment but is one of the elements of the surveys resources.

The constraints on a resource survey can take many other forms. Before the survey becomes operational, the sponsor of the survey may have already determined the area to be investigated, the type of fish stocks to be considered, and the vessel to be used as well as the amount of money to be included in the budget. The first section of this chapter was written to emphasize an environmental component of most surveys - which is often overlooked or not taken into consideration, as well as it might - the needs and requirements of investors in fisheries.

The investors requirements are one of the most important components of a survey's environment. In fact there may be a large schedule of requirements stemming from the constraints on the survey. Often these constraints are the requirements for data or information from the survey by people outside the survey. These demands for information cannot usually be influenced by the survey itself - they are "given" - and yet by their nature these requirements influence the surveys performance.

Determining the elements of constraint on a survey is a job which needs to be done systematically and continuously. The survey that fails to perform properly may do so because the manager has erroneously determined that some aspect affecting the surveys performance is not subject to change or control. For example, a survey may exhibit a poor performance if the manager determines that some objective is fixed, such as going ahead to estimate the initial catch rates that could be realized by commercial fishing boats even though a commercial fishery is already in operation. On the other hand, the manager that reviews the problem of objectives and accurately determines which objectives of the survey should remain fixed and which ones should be changed, increases his chances of success.

The test for determining if a feature of the survey should be considered within its environment is to ask two questions: "Can the survey do anything about it?", and "Does it matter relative to the objectives?". If the answer to the first question is "No" but to the second "Yes", then "it" is in the survey's environment.

2.3.3 The survey's resources

When the resources of the survey are considered they are usually set out in terms of money, man/months, and equipment. These are the means by which the survey accomplishes its job. The survey director decides how to use his resources: He decides who shall do a particular job, how much money to spend on an activity, or what time limits to place on work to be done. Besides men, machines and money, many intangibles may be included among the list of resources available to a project. The degree of skill of the scientists on the staff, new technological developments that can be put to use, and the amount of "good-will" enjoyed by the survey among the people coming in contact with it, are also in the pool of the survey's resources.

The good survey manager will pay attention not only to manipulating his existing resources but in looking for opportunities for increasing his resources for the future. In this respect, he may initiate training programmes or spend some of his existing resources for technological research and development, such as developing a new sampling gear or a better technique of fishing.

2.3.4 Components of the survey

Defining the components of a survey can be thought of as the division of all the tasks the survey must perform into related functions or activities. A useful way the manager can think about the real components of his survey project is to break away from the traditional rigid designation of departments such as "biology", "gear technology", or "economics" and think instead in terms of missions to be accomplished. The reason for separating the survey into components is to allow the manager to receive the kind of information he needs, in order to judge if the survey is operating properly and to decide what should be done next. This division is a practical matter because no one is able to view and understand the direction of a large survey as a whole without sub-dividing the problem. However, the manager must avoid setting out his components into a rigid matrix which, in a particular situation, may be optimum but which will be horribly difficult to manage if the situation changes - and change it must if the project's objective is not to hold the status quo. In situations where the designation of responsibilities has become rigid or impossible to change, a hardening of the arteries of communication sets in with the manager (the brain), eventually receiving no useful information with which to make proper decisions and left unable to respond to changes in the survey's environment or resources, or to control its outcome.

The manager should try to divide his survey work into components (missions) whose measures of performance can be closely related to the measure of performance of the overall survey. For example, he may designate that a team consisting of a stock assessment expert, a gear technologist, a fishing expert, and a business management expert, be charged with the responsibility of determining if a fishery development opportunity exists for some class of investor and, if it does, of making an investor aware of the opportunity and advising him on the best way to proceed. The performance of this mission-oriented team can be judged by the survey's measure of performance we assumed in earlier examples - namely, the timeliness and usefulness of information given to investors. On the other hand, the manager may set out components such as the "biology department" charged with the responsibility of providing all biological information needed by the project, or an "engineering department" to provide all the answers to engineering or technological problems. But the value, success, or failure of these components is difficult if not impossible to measure in terms of meeting the project objective (i.e., development of a fishery) because the performance measures of the components are not closely related to the measure of performance of the overall project (i.e., a viable fishery instituted).

2.3.5 Survey management

The final item of the list of considerations appearing at the beginning of this section is the management or direction of the survey. The management of the survey deals with generating plans for the survey, i.e., the considerations of the overall goals, the environment of the survey, the utilization of the survey's resources and its components or missions. The management sets out the objectives, assesses

the effects of constraints, and allocates the resources to guide the survey's performance. Besides planning, the manager must also insure that the various activities and functions are carried out according to the plan, and if they are not he must determine why and correct the situation.

The information needed by the manager to carry out the survey planning and direction must not be neglected. In any resource survey, information required for project planning and direction should be gathered simultaneously with the data required to meet the objectives. In most cases both types of information should be analysed as the survey progresses.

If the estimates of standing stock, catch rates, and potential yields are calculated periodically, say after each cruise, or complete coverage of the area, the survey will be in a position to de-emphasize these objectives at the time when enough data have been collected to give the required precision to the estimates and satisfy those who require the information. Of course, the realization of what is good enough involves the simultaneous assessment of the requirements of those persons who will take decisions based on the facts developed in the survey. This means the survey must be aware of the information required by the potential investors, and others who are interested in the management of the project or the resource.

A resource survey conducted in this manner can be considered an iteration process, and treated as such with some techniques of systems analysis. This means that the assumptions, hypotheses, and objectives of the survey change from time-to-time as the survey progresses. These changes are brought about as a result of subjecting the survey results to criteria of satisfaction whenever a cycle through the sampling process is completed. After each cycle we should ask whether or not those who must take decisions are satisfied with the results. If the results are not satisfactory, the experience and knowledge we have gained should be used to adjust the assumptions, hypotheses and objectives of the next cycle. In this manner the project will not loose sight of the immediate objectives and requirements, nor waste energy and money refining estimates that are already at the required level of precision. On the other hand, critical evaluation of the up-to-date results will lead to an evaluation of the survey strategy and operations as the work proceeds; thus allowing an adjustment to the survey as new problems are recognized or new techniques of attacking them are developed.

What does treating the survey as an iteration process mean in terms of the practical application of the survey results to managing or developing the fishery? It means, for instance, that the project is less likely to spend all its vessel time and operating funds estimating potential yields, only to realize to late that no information is available on what an actual fishing operation could produce. The survey is also less likely to spend its entire time searching for concentrations of fish to simulate a commercial fishery operation only to finally realize that it is not known what proportion of these concentrations can be harvested without undue harm to the stock.

3. SCOPE OF RESOURCE SURVEYS

The following section is taken from the Manual of Methods for Fisheries Resource Survey and Appraisal, Part 1. Survey and Charting of Fishery Resources.

3.1 Selection of species

If the survey's environmental constraints or the information it is required to supply is narrowly defined, the establishment of work priorities among species, species groups, etc. may not require special attention. On the other hand, if the assignment given is general, e.g. investigate the fishing potential of a particular locality, a judgement has to be made concerning the order in which to survey certain species, ecological and taxonomic groups. For such a general type of assignment a number of factors must be evaluated. Important among these are:

(1) What information exists concerning the fauna of the region?

(2) What species are of local interest and use?

(3) Can adequate sampling systems be devised for species of interest and what are the logistic and operational problems?

(4) What factors limit the use of the several species once information on the resource base has been established?

For planning the fisheries surveys, it is helpful for the field investigators to make a brief compilation of information on distribution and behavior of the same or related species in other areas where they are already extensively harvested.

3.2 Selecting the study area

The field investigators often do not have to make decisions about the area in which to conduct a survey. This is frequently laid down by the operational limitations given. There are times, however, when options are given in selecting the survey area. In such instances the investigator must consider the known distribution or behavior patterns of the species or species groups to be studied, its (or their) distribution pattern relative to oceanographic and/or substrate features. Often the information will be fragmentary but adequate to localize surveys in the most promising zones, i.e., demersal fish studies will be restricted "a priori" to the continental shelf and upper slope regions, certain tunas or other pelagic fishes are restricted to known thermal ranges, etc.

For demersal studies, the survey area may be limited if data are available concerning the distribution of a species related to substrate or the bathymetric range of the exploitable sizes of the population. If the total demersal fish complex is the objective of the survey, then it is important to recognize that existing demersal fisheries frequently operate to depths of at least 1000 m. Hence, the selected survey area may well include the greater part of the continental shelf and slope down to this depth. Modification of the study area may take place as a result of feedback from early survey activities. Similar consideration must be given to shellfish surveys.

For pelagic fish studies, the investigator may have less tangible reference points, and hence must rely on antecedent knowledge of distribution patterns of species or species groups related to hydrographic factors (temperatures, currents, upwelling zones, areas of high basic productivity, convergences, etc.). A number of oceanographic atlases are now available which incorporate both physical and biological information of this character.

In addition to those factors that relate to the general ecology of the species being sought, the investigator should consider the logistic problems of the research vessel as well as those of the fishing fleet that might take advantage of positive results achieved. Quite often, however, in some areas there is no suitable fleet available to take advantage of a newly discovered fishable stock. The type, range, etc. of the future fleet required to exploit the resources discovered will have to be decided on the results of the

exploratory work done, but initially the primary task of the survey is to map the resources wherever they might be within the overall limits of the survey area. However, if there is no clear choice provided by the available information on the distribution patterns of the species to be studied, and a local fishing capacity exists, then it is better to initiate the investigation in areas which are adjacent to port facilities and for which logistic aspects are such that they are likely to enhance fisheries development. Systematic expansion over alternate areas can be similarly selected.

3.3 Selecting vessel and gear

The choice of a vessel for exploratory fishing is important since it will have a direct influence on survey range and duration, the types of sampling gear that can be employed etc. However, in most cases, this selection is predetermined by the vessels already available or by the type of vessels to be chartered. In considering selection of a platform to conduct survey activities, one must of course consider the operational logistics in the area of operation, type of gear to be used from the vessel, and the needs of scientists as related to laboratory space, etc. If advanced acoustic equipment is to be employed, space required for equipment and operators must be included.

For many surveys, a trawler will be the best choice because of its greater versatility compared to other types of vessels. With suitable deck arrangements, a trawler, particularly of the stern trawler type, is able to effectively operate and handle all types of bottom trawls, including shrimp trawls and high opening trawls for demersal species, mid-water trawls for small pelagic species, as well as dredges and bottom samplers.

Once the area of investigation and survey objectives have been determined, plans must be laid for the sampling activity. The type of gear selected depends on the specific objective and the purpose for which the sampling gear will be employed. For example, if the sampling devices are to be used to develop indices of abundance, the selection of the gear may be different from that required for merely identifying targets detected during acoustic surveys.

The selection of sampling devices is always difficult and will depend on the objectives of the investigation and on the anticipated user of the information. From a scientific standpoint, one might want to use the most up-to-date trawl or other sampling devices, or a scaled-down version of some particular commercial gear. One should, however, be aware of the fact that if the equipment is too atypical of that normally employed by fishermen, both the scientist and the fishermen may have difficulty interpreting results because they may not reveal the commercial potential of the stock (Alverson and Pereyra, 1969).

Once the investigator has selected and tested his gear and is reasonably satisfied with it as a sampling device, it is important that gear and procedures be standardized.

It should, in this connection, be emphasized that resource assessment surveys do not constitute a programme in gear design, nor can one continue to experiment "ad infinitum" in an attempt to refine the gear to optimize catch rates. Such surveys have as their primary objective the determination of distribution and relative abundance patterns as well as first approximations of exploitable stock size. In this purpose, the sampling device does not necessarily have to be the most efficient fishing system and/or the fishing strategy perfected. In most instances, these problems will be considered during the subsequent stages of development of the fishery.

Regardless of what type of sampling gear is chosen, it is important that the investigator be familiar with its structural and fishing characteristics. For example, if a trawl is chosen, what are its dimensions, mesh sizes and tapers, what bridle system is employed, and what size of doors are to be used with the trawl? In this latter regard, the spreading device, doors, or floats, must be large enough to achieve an adequate spread and vertical opening of the net. It is also important to know the attitude of the gear during fishing; e.g., under normal towing speeds, that vertical and horizontal openings are actually achieved.

For purse seines, similar information is required concerning its length and depth, mesh size, hanging ratios, etc. The sinking rate, time required to complete pursing, and potential sampling volume are all important factors.

If the gear or vessel to be used for the survey are not of a type in commercial use, comparisons with commercial vessels should be conducted whenever possible. Selection of a relatively standard fishing gear is generally advisable since it allows some immediate interpretation of the economic aspects of resources.

4. THE SAMPLING SCHEME OF THE SURVEY

4.1 Precision and accuracy of resource survey estimates

The results of resource surveys are always subject to some uncertainty. This uncertainty has two components: the degree of accuracy and the degree of precision of the survey estimates. In the statistical sense accuracy refers to size of deviations of the survey's estimates from the true estimates while precision refers to the size of deviations from the estimated mean calculated from repeated applications of the same sampling procedures.

The accuracy of survey estimates is influenced by the biases introduced through errors in measurement or the inaccessibility of certain portions of the fish populations that are being studied. The biases introduced by vulnerability, gear selectivity, or accessibility of the fish affects the accuracy of estimates referring to the whole population.

On the other hand, the precision of the estimates, even if they are biased is influenced by the number of samples taken, the manner in which the samples are drawn, and the way the data are analyzed.

Improvements in the accuracy and precision of the survey estimates costs time and money. Consequently, the specification of the degree of precision needed in the results and some investigation into the biases of the survey technique is important. The specification of precision is usually the responsibility of the sponsor of the survey or the person who is going to take a decision based on the data. In the terminology introduced in Section 2, the precision is an environmental constraint. On the other hand, the survey itself must eliminate as much of the biases as it can, with the resources available to it, by control of the techniques and operations. The communication of the results of the survey to the person taking a decision should include an idea of the degree of precision and possible sources of biases in the estimates. This may present difficulties, because many administrators are unaccustomed to thinking in terms of the amount of error that can be tolerated in estimates, consistent with making good decisions (Cochran, 1963).

Considering the nature of various fishery resources, it is clear that some types of estimates will be more precise than others given an equal and fixed amount of money or effort to make the estimates. For instance, it is easier and less costly to estimate the size of demersal stocks at a given level of precision than it is to estimate pelagic stocks to the same level. By the same token, it is easier to estimate the projected operating costs of fishing vessels than to estimate projected profits or values of catches to the same level of precision.

Generally speaking, some measure of the precision of estimates from resource surveys is usually possible. A statistically designed survey, such as one utilizing some form of probability sampling, has the advantage of producing internally generated estimates of precision. However, even without probability sampling, some indices of precision can also be made. But these usually, in final analyses, rely on the judgement of an individual concerning the "reasonableness" of certain variables, and are subject to criticisms and arguments stemming from the objectivity or lack of it attributed to the judge. Nevertheless, in such cases a range for an estimate based on subjective intuition or objective study is useful. For instance, in computing the first estimates of maximum biological potential yield according to the relationship $C\,max = 0.4\,MB$ (where $C\,max$ is maximum sustainable catch, M is the instantaneous rate of natural mortality, and Bo is the virgin biomass), a range for the estimate can be given as a measure to indicate the precision of the estimate. This can be computed by substituting two values of M in the equation to yield an upper and lower estimate of $C\,max$. The two values of M that are chosen are the upper and lower limits of "reasonable" values as judged by the investigator. Thus, even if age determinations, growth parameters and natural mortality rates have not been determined for a particular species in an area, it is useful to estimate the likely range of M from known mortality rates of similar species and perform the calculations for potential yield.

In addition to calculating a range for the estimate of potential yield from a range of natural mortality rates, it may be useful in some cases to perform the calculations for a range of vulnerability coefficients as well. The vulnerability coefficient, q, used to estimate the virgin biomass from trawl surveys refers to the proportion of fish in the path of the net that are actually caught.

Of course these efforts to give the decision maker an idea of the precision of the estimates must be tempered by the realization of the degree of accuracy (bias) of the overall survey. The resources spent to improve precision should be in line with the overall objectives of the survey and the amount of accuracy it is possible to achieve in all the factors that influence the final outcome. Nevertheless, in most cases the success of a survey in achieving a measure of precision in the estimates it produces can be improved by using some form of probability sampling.

4.2 Probability sampling

As previously mentioned, probability sampling to estimate the items of interest to a survey has the built-in advantage of yielding a measure of precision of the estimates. In turn, a knowledge of the estimate's precision helps one to draw sound conclusions about the meaning of the estimates and therefore to make better decisions. To many fisheries workers the subject of probability sampling is complex and appears rife with details of procedure that differ in a multitude of situations. Though sampling theory has made tremendous gains in modern times and many of its procedures in highly specialized situations are complicated, the basic theory and practices are a very practical and cost-effective method of operation for fisheries survey work.

Probability sampling can be defined as the group of sampling procedures with the following common properties. (Cochran, 1963)

(1) The set of distinct samples (S_1, S_2, . . . S_n) that are capable of being selected from a specified population can be defined.

(2) Each possible sample, S_i, has a known probability of being selected.

(3) A sample is actually selected according to its known probability of being selected, i.e., randomly sampled.

(4) The method of obtaining estimates (such as the average value of the elements in a sample) from the sample must be stated and must yield a unique estimate for any specific sample.

All probability sampling theory and procedures are based upon these underlying properties. By way of contrast Cochran has pointed out some cases of non-probability sampling which do not have a random element of selection.

(1) Samples are restricted to that part of the population that is readily accessible, e.g., sampling only the fish near the top of the container.

(2) Selection of samples haphazardly without conscious planning, e.g., sampling at stations that are less bothersome to get to.

(3) Selection of samples that seem "typical" to a sampler of a small but heterogenous population, and

(4) Comprising a sample of "volunteers" especially when the measuring process is unpleasant or troublesome.

Any or all of these selection processes may be useful under the proper conditions but the only way of determining how good one of them may be is to compare the sample results to the results obtained by examining the whole population. Even then, if a method appears useful there is no guarantee it will remain so under different circumstances.

Several methods exist for statistically sampling for stock sizes, biological attributes, hydrographic features or oceanographic conditions during a resource survey. The procedures of selecting samples, and hence the techniques of analyses, characterize the various methods known as: 1) systematic sampling, 2) systematic sampling with a random start, 3) completely random, 4) stratified random sampling, 5) double sampling, 6) cluster sampling, etc., and procedures mixing two or more of these.

Details of each method can be found in any of a number of good sampling texts (see bibliography); but investigation of all but the most important techniques would be too lengthy to discuss here. However, one important feature - the characteristics of the item being sampled - that governs the selection of a particular procedure should be discussed to put latter sections of this discussion on stratified sampling into perspective.

The distribution characteristics of the item or items under investigation determines which of the methods is needed or which will be the most cost-effective in any situation. Cochran (1963) has classified the items of sampling into four types based on agriculture surveys; taking his suggestions and applying them to fish distributions, we can see that the type of sampling that is required relates directly to the behavioral characteristics of the fish under investigation (Table 4.2.1).

Table 4.2.1. Examples of different types of fish distribution and the type of sampling needed

Type	Characteristics	Type of Sampling Needed
1	Widespread throughout the area, occurring with reasonable frequency in all parts.	A general survey, with low sampling ratio, e.g., systematic or simple random sampling with relatively few samples drawn.
2	Widespread throughout the area but with low frequency of occurrence.	A general survey as above but with a higher sampling ratio.
3	Occurring with reasonable frequency in most parts of the area, but with more sporadic distribution, being absent in some parts and highly concentrated in others.	For best results, stratified sampling with different intensities of sampling in different parts of the area. If the species is of relatively low interest, compared to others of type 1 or 2, it can sometimes be sampled as part of a general survey with supplementary sampling.
4	Distribution being sporadic or concentrated in a small part of the area.	Not suitable for a general survey in which sampling is conducted fairly evenly over the area. Requires sampling geared to its distribution, e.g., stratified sampling.

Depending to some extent on how one chooses to define the area under investigation or perhaps the time of the year of the investigation, it can be generally stated that fish amenable to trawling are of type 3 or type 4 in their distribution characteristics. That being so, Cochran tells us that stratified random sampling is perhaps the best method to employ to measure these fish stocks or characteristics of them.

An illustration of the gains in precision to be gotten from using stratified random sampling rather than simple random sampling is given in the following example.

4.2.1 Comparisons of the standard error of the mean under simple random and stratified random sampling

As an example, suppose the following 11 ($n = 11$) observations were taken by simple random sampling from a population of 100 items ($N = 100$):

$$y_i = \{1, 1, 2, 2, 3, 3, 5, 5, 5, 7, 7\}$$

The mean value is simply

$$\bar{y} = \frac{\Sigma yi}{n} = \frac{41}{11} = 3.72$$

The standard error of this mean is

$$s_{\bar{y}} = \sqrt{\frac{N-n}{N}} \sqrt{\frac{\Sigma y^2 - \frac{(\Sigma y)^2}{n}}{n(n-1)}} \quad \text{or} \quad \sqrt{\frac{100-11}{100}} \sqrt{\frac{201 - \frac{1681}{11}}{110}} =$$

$$\sqrt{0.89} \sqrt{0.4380} = 0.94 \times 0.66 = 0.62$$

Now suppose that the 100 possible observations in the population could be stratified (grouped together for sampling purposes) into relatively homogeneous groups before the sample was drawn. These conditions and subsequent calculations are illustrated in Table 4.2.2.

Table 4.2.2 Stratification of the population and sampling results

Stratum number		1	2	3	Totals
Values in the stratum		1's and 2's	Only 3's	5's and 7's	
Number of units	N_h	40	10	50	100 = N
Number of units in the sample	n_h	4	2	5	11 = n
	$N_h - n_h$	36	8	45	
Stratum weight	$W_h = \frac{N_h}{N}$	0.4	0.1	0.5	
Sampling fraction in stratum	$f_n = \frac{n_h}{N_h}$	0.1	0.2	0.1	
Sample values	y_{hi}	1, 1, 2, 2	3, 3	5, 5, 5, 7, 7	
Sum of sample values	Σy_{hi}	6	6	29	$41 = \Sigma\Sigma y_{hi}$
Sample mean within stratum	$\frac{\Sigma y_{hi}}{n_h} = \bar{y}_h$	1.5	3	5.8	
Estimated stratum totals	$N_h \bar{y}_h$	60	30	290	$380 = N_n \bar{y}_h$
	Σy_{hi}^2	10	18	173	
Stratum variance	$s_h^2 = \frac{\Sigma y_{hi}^2 - \frac{(\Sigma y_{hi})^2}{n_h}}{n_h - 1}$	0.33	0	1.2	
	$\frac{s_h^2}{n_h}$	0.0825	0	0.240	
	$N_h(N_h - n_h)$	1440	80	2250	

Under stratified random sampling the estimated population mean per unit is

$$\bar{y}_{st} = \frac{\Sigma N_h \bar{y}_h}{N} = \frac{380}{100} = 3.8$$

and the unbiased estimate of the variance of $\bar{y}_{st}$ is

$$s^2(\bar{y}_{st}) = \frac{1}{N^2} \Sigma N_h (N_h - n_h) \frac{s_h^2}{n_h}$$

$$= \frac{1}{10000} [(1440 \times 0.0825) + (80 \times 0) + (2250 \times 0.240)]$$

$$= 0.0001 [(118.8) + 0 + (540)] = 0.066$$

the standard error of $\bar{y}_{st}$ is $s_{\bar{y}(st)} = 0.257$

An alternative form for the variance of $\bar{y}_{(st)}$ which is more convenient for computing is

$$s^2_{(\bar{y}_{st})} = \sum_{h=1}^{L} \frac{W_h^2 s_n^2}{n_h} \quad \sum_{h=1}^{L} \frac{W_n s_n^2}{N}$$

For the given example the results would be

$$s^2_{(\bar{y}_{st})} = [(0.16 \times 0.825) + 0 + (0.25 \times 0.24)] - \frac{[0.4 \times 0.33 + 0 + 0.5 \times 1.2]}{100}$$

$$= [0.0132 + 0.06] - \frac{(0.132 + 0.6)}{100} = 0.066$$

A comparison of the results of the two methods is given in Table 4.2.3.

Table 4.2.3 Sampling Method

	Simple random	Stratified random
Estimated population mean	3.72	3.8
Estimated population total	372	380
Standard error of the mean	0.62	0.26
95% confidence limits of the mean[1]	3.72 ± 1.36	3.80 ± 0.60
Confidence interval of the mean	2.36 - 5.08	3.20 - 4.40

[1] Simple random sampling confidence limits are computed as $\bar{y} \pm ts$ and those for stratified sampling as $\bar{y}_{(st)} \pm ts(\bar{y}_{st})$ where the t value is student's t with n-1 and n-L degrees of freedom respectively. For the example t values of 2.2 and 2.3 were used.

In this example stratified random sampling which utilizes the information about the distribution of the values in the population, gives a sampling error that is less than half that of simple random sampling (0.26 vs. 0.62) and therefore higher precision of the estimate even though the observations drawn were the same and the estimated mean values of the population given by the two methods are

about the same. The reduction is standard error in stratified random sampling under proper stratification indicates that one can gain more assurance of the correctness of conclusions drawn about the mean value than was possible with simple random sampling. A glance at the confidence intervals will illustrate that fact. With increased assurance that the conclusions are correct one has increased assurance that decisions made as a result of those conclusions will also be correct. In other words, the margin of error under stratified sampling with proper stratification is less than that of simple random sampling.

In most situations to be found in fisheries work where stratified random sampling is at all applicable it will yield gains in precision over simple random sampling. Only in situations where the stratum sample sizes n_h are far from optimum (see later chapter) will this not be true; but in cases where the strata are reasonably homogeneous, and where finite population corrections can be ignored (they were taken into consideration in the example), the variances given by stratified random sampling with either optimum allocation of sample sizes or proportional allocation will be smaller than those given by completely random sampling.

4.3 The procedure of stratified random sampling

We have seen that more precise estimates can usually be made by using the well-known technique of stratified random sampling (SRS). In this section the application of SRS to resource surveys will be discussed. Under the SRS system the survey area is divided into a number of homogeneous sub-areas or strata which are treated independently. When the strata boundaries have been determined, the positions of the sampling stations within them are drawn at random.

The question arises as to what is the best characteristic for defining and constructing the sub-areas or strata. For estimating a single item such as an abundance of a particular species, the best characteristic is the relative distribution of the species itself. The next best is the relative distribution of some other characteristic highly correlated with the species distribution. In practice, however, we seldom seek a single estimate, nor do we know precisely the relative abundance of a species before the survey; sometimes we do not even know the distribution of depth, bottom types or oceanographic features. In the latter case the stratum boundaries must be determined with a preliminary survey to determine the most likely characters to be used for stratification and the distribution of these characters over the entire survey area.

Rarely, however, are we completely ignorant regarding the fish distribution. We may know the distribution of variables such as depth, bottom type, salinities, etc., which may be correlated with fish concentrations or relative abundance over the area. But the opinions based on experience of local fishermen, the master fisherman, and the biologist in charge may be of more practical value for stratifying the area. These opinions based on an understanding of fish behavior may save time and expense of preliminary surveys. For instance, a master fisherman and biologist studying a fairly detailed navigation chart and other available information, may be able to outline with a fair degree of accuracy, which areas will likely produce catches that are, say, excellent, very good, fair or poor. They may also suggest the seasonal differences in availability that are likely to occur in the areas. Further, the criteria for designating the various strata may be well defined and of objective use, even though the relationship of fish distribution to the criteria is subjective. If this is true, these criteria can be used to systematically stratify the whole survey area. Even if the criteria cannot be set out very objectively, the stratification may still be of value. However, in this case the stratification must be tested in the initial cruises and changed if it does not divide the total area into homogeneous sub-areas of different fish concentrations.

After the stratification is complete, the total number of samples (hauls) are allocated among the strata either proportionally to the size of the strata or preferably, based on the expected variation in the catch per haul in the strata. In the latter case more samples can be allocated to the strata for which the most variation is expected or more precise estimates are needed. For most purposes an allocation of samples based on both relative area and relative variation will be most efficient.

If the stratification is done correctly the variation in fish catches in the sample hauls should be greater between the strata than within them.

The stratification of the survey area should be done with the important species or species groups in mind. Naturally the strata defined under this procedure will be most efficient for estimating these species taken into consideration during stratification and less efficient (or entirely inadequate) for the remaining species.

Usually for administrative convenience, only one set of strata is defined. However, in some cases, when a large variety of stocks must be investigated there may be a need to define more than one set of strata and, in effect, conduct two or more superimposed studies, treating various groups of fish separately. This procedure is taken as a matter of course for resource surveys investigating the widely divergent pelagic and demersal stocks. However, the investigator should give consideration to developing more than one set of strata if he finds that those he has defined are inefficient or inadequate for estimating the potential yield of some important groups within the required precision. Finally, it should be noted that each time the survey is repeated, a new set of stations should be determined.

4.3.1 Summary of stratification procedure

(1) Choose the important species or species groups for which strata are to be defined.

(2) Obtain detailed charts of the area showing the distribution of bottom types, depth contours, river influences, currents, reefs, etc. If detailed charts do not exist one should be drawn to show the oceanographic features of the area, which can be learned from a search of the literature and from interviews with local fishermen. If these are lacking, preliminary cruises may be needed to characterize the area before the actual resource surveys begin in earnest.

(3) From the preliminary survey, fishermen's interviews, and opinions of knowledgeable persons, construct a profile or list of the oceanographic features of the area that are likely to be positively or negatively correlated or with relative fish distribution. If the seasonal variations in fish distribution or availability are fairly well known, these facts should also be set out.

(4) (a) Using the information and opinions set out in steps 1 through 3, outline the areas on the charts which are expected to be the areas with the heaviest concentrations of the species under consideration. At this stage little attention should be paid to whether or not these areas might also be the best fishing areas for the gear you intend to use.

(b) Next, outline the areas on the chart which you expect will contain no individuals of the species you are considering. For example, outline the extremely deep areas for relatively shallow water species or non-muddy bottom areas for species closely associated with mud, etc.

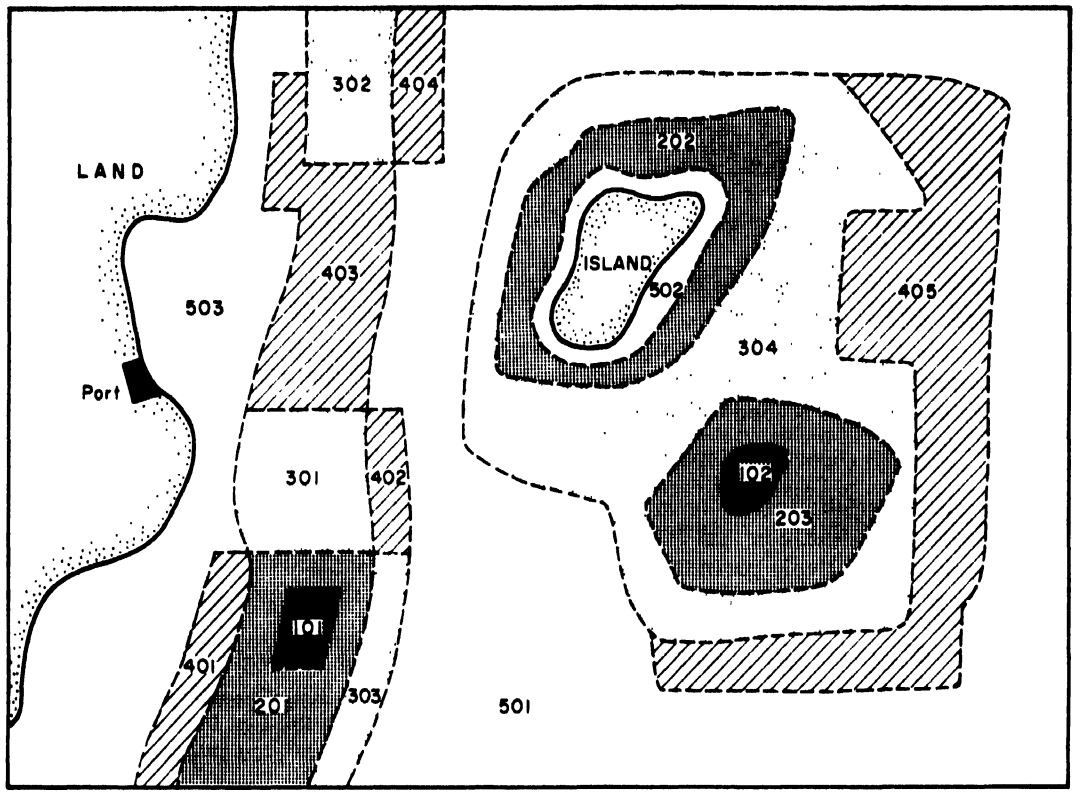
(c) The remaining area can be further sub-divided into 2, 3, or 4 strata which are expected to range in fish concentration between the two extremes thus far outlined. These strata can be labeled very good, good, fair, poor. Sometimes the correlations of fish distribution or concentration with the oceanographic features will be almost perfect (i.e., reefs and reef fish); in these cases only the two strata given in (4) (a) and (b) are required, unless it is decided to study in detail the differences among reefs, then in statistical parlance, each reef would constitute a stratum.

(5) When the entire survey area is divided into strata which are thought to be as homogeneous in fish distribution as practical, one may have a chart resembling Figure 4.3.1. As can be seen from the diagram, the strata can be comprised of discontinuous widely spaced sub-units. Each sub-unit of a strata is numbered within the overall stratum code number.

For example:

Stratum	Stratum number
Highest density	1
High density	2
Medium	3
Low	4
Very low	5

SURVEY AREA



STRATUM NUMBER	SYMBOL	EXPECTED CATCH RATES	EXPECTED RELATIVE FISH DISTRIBUTION
1		EXCELLENT	HIGHEST DENSITY
2		VERY GOOD	HIGH DENSITY
3		GOOD	MEDIUM DENSITY
4		FAIR	LOW DENSITY
5		POOR	VERY LOW DENSITY

Figure 4.3.1

For most stock assessment purposes, especially computing potential yields, the strata will be the smallest unit to be used in the analysis. However, for other purposes, such as estimating vessel operation costs and profits, determining vessel development strategies, etc., the sub-units themselves can either be considered separate strata or grouped by other criteria such as distance from port into another set of strata. Therefore, it is well to preserve the identity of these sub-units to facilitate the data processing for these secondary analyses.

(6) The area of each strata is computed with a planimeter. If the stratum boundaries are defined by depths or other features for which the precise locations are not yet known, the fixing of the stratum boundary and the computation of area can be deferred until the exact location can be determined from a cruise. If this is required it should be the objective receiving the emphasis during initial cruises.

(7) The strata are further divided by a grid into small equal area squares or sampling units for the purpose of randomly selecting sampling sites. The squares of the grid should be very small in relation to the area of the stratum;[1] but the areas need not be smaller than four times the square of the accuracy of navigation.[2] Each square in the grid is assigned a reference number, beginning with 1 for each sub-unit. The reference numbers corresponding to positions should be chosen from a random number table (without replacement) to indicate the sampling sites of the cruise. The number of sites chosen within each stratum or sub-unit is discussed in the next section of this paper.

The grid pattern, referred to in the previous paragraph, is intended to illustrate the process of dividing the strata into sampling units. The grid itself need not be drawn on a chart. In fact, a coordinate reference system is most often used for choosing the sampling units at random. One random number is drawn first to fix the horizontal location, then another one is drawn to fix the vertical position (see illustration). Pairs of random numbers that correspond to positions outside an irregularly shaped area are ignored.

Two methods may be used to select random numbers. In both, the horizontal and vertical grid units should be numbered beginning with zero (e.g., for 16 grid units vertically, grid units are numbered 0 to 15).

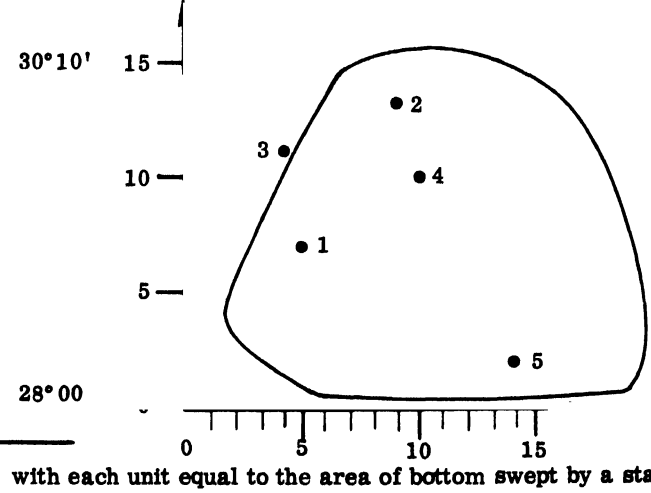
Method 1: Select random numbers from a random number table, rejecting those greater than the largest grid unit number.

Example: In the horizontal direction, reject random numbers greater than 19.

In the vertical, reject random numbers greater than 15.

Random numbers chosen for four sampling sites

no.	Horizontal	Vertical
1	5	7
	32 reject	
2	9	13
3	4	11 ignored
	12	96 reject
4	10	10
5	14	2



[1] In theory the strata are divided into small units, with each unit equal to the area of bottom swept by a standard length tow. The number of such units will be used in the analysis, but for purposes of selecting the sampling sites the units can be much larger.

[2] If navigation accuracy is say ± 1 mile the squares need not be smaller than 4 $x_1 mi^2$ = 4 mi^2.

Method 2: Call NGU_h the number of grid units in the horizontal direction (e.g., 20);

NGU_v the number of grid units in the vertical direction (e.g., 16);

$LIMIT_h$ the largest integral multiple of NGU-H less than 101 (e.g., 100 = 20 x 5);

$LIMIT_v$ the same for the vertical (e.g., 96 = 16 x 6).

Select random numbers, first rejecting those greater than $LIMIT_h$ (or $LIMIT_v$). The corresponding grid unit equals the remainder when the random number is divided by NGU_h or NGU_v.

An example of this method which lends itself to computer generation of the random sampling sites is given in Table 4.3.1.

Table 4.3.1. An example of random numbers chosen for four sampling sites

Horizontal			Vertical		
$NGU_h = 20$ $LIMIT_h = 100$			$NGU_v = 16$ $LIMIT_v = 96$		
Random Number	Computation of Remainder	Grid Position	Random Number	Computation of Remainder	Grid Position
5	$[\frac{5}{20} = 0$ r. 5]	5	39	$[\frac{39}{16} = [2,$ r. 7]	7
49	$[\frac{49}{20} = 2$ r. 9]	9	13	$[\frac{13}{16} = 0,$ r. 13]	13
84	$[\frac{84}{20} = 4$ r. 4]		98	[98>96]	reject
84		4	91	$[\frac{91}{16} = 5$ r. 1]	1 ignored
70	$[\frac{70}{20} = 3$ r. 10]	10	42	$[\frac{42}{16} = 2$ r. 10]	10
14	$[\frac{14}{20} = 0$ r. 14]	14	2	$[\frac{2}{16} = 0$ r. 2]	2

(8) After the first complete coverage (sampling in all strata) and again at least after the first year of operation, the boundaries of the strata should be reviewed in the light of the sampling results. If serious deficiencies exist, start again at step (4) (a), change the boundaries and recompute the areas, number of sampling units, etc.

4.3.2 Factors influencing the allocation of samples to strata

Under the stratified random sampling scheme, the area containing the natural fish populations under study is divided into strata that are reasonably homogeneous for relative fish density or homogeneous for characters correlated with fish density (e.g., bottom type, depth, etc.). The strata in turn are divided into sampling units equal to the area swept by a standard length tow.

Two questions now arise: how many samples (tows) should be drawn from each stratum; and, how should the sampling be conducted?

The answer to how many samples should be taken from each stratum lies in the assessment and consideration of:

(1) total number of samples possible, considering the manpower, finances and vessel time available to the survey;

(2) the number of times a complete coverage of the entire survey area within a season is necessary;

(3) expected variation in the catch from tow to tow, within each stratum;

(4) the sizes of the strata (number of sampling units);

(5) the degree of precision needed in the estimates of stock density, biomass, and potential yield in each stratum;

(6) expense of sampling in each stratum;

(7) importance of the strata from points of view other than that of stock assessment.

4.3.3 A procedure for allocating samples among the strata

In most operational FAO projects the first item of the list will be of most importance. Constraints will already exist on the manpower, finances, and vessel time available for the survey. In this sense the maximum number of days at sea is pre-determined. The problem then becomes one of how to get the most samples for the given number of days at sea and still allocate the samples to strata within the constraints set by the other factors. A process for determining the number of samples to be allocated to each stratum is described in the following procedure:

(1) Estimate the number of cruises and days per year that the vessel or vessels will be able to work at sea. Consider:

(a) the range of the vessel

(b) frequency of weather conditions that preclude safe or effective operation

(c) mechanical condition of the vessel and its equipment and the time needed for repairs or overhauls

(2) Divide the estimated number of working days at sea per year by the number of times per year that a complete coverage of the area is required. It is good practice to cover the entire area as many times as possible during a year. Nevertheless, a complete coverage (sampling in all strata) will usually be required at least once a year. If seasonal differences are pronounced the entire area (all strata) should be covered more frequently, allowing, of course, for those seasons when normal operations are not possible due to weather. This estimate of the number of days per season to be given to sampling the entire area under consideration, multiplied by an estimate of the number of samples per day of operation, will form the basis of the overall sampling intensity.

(3) Determine the relative sizes of each strata (ratio of stratum area to total area of all strata).

(4) With no other factors taken into consideration, the number of samples for each stratum could be determined by the relative strata sizes alone - sampling in proportion to stratum size. In this case, the sample sizes are calculated from $N_h = Np_h$ where N_h is the number of samples to be taken in stratum h (rounded to nearest whole number), N is the estimated total number of samples possible for all strata, and p_h is the ratio of the hth stratum area to the total area. Proportional sampling among the strata in almost all cases will result in smaller variances of estimated means or totals that would be given by comparable simple random sampling.

However, in most surveys the variances can be reduced even further by making additional considerations before allocating the samples. In almost all situations, the strata containing the highest densities of fish are small in area in relation to the total area, but contain more fish. Because these high-density areas will most likely be those where a fishery develops, they are more important than their relative sizes alone would suggest. Sampling only in proportion to area in this case will result in fewer samples in the productive areas than would generally be required to reach an acceptable level of precision in the estimates of biomass and average catch rates. The next item shows how the expected variation within the strata and the relative importance of the strata can be taken into consideration.

(5) Sampling in proportion to stratum sizes yields gains in precision over simple random sampling. Similarly, optimum sampling - the allocation of the samples in proportion to the relative variance of the catch rates within the strata - leads to further gain. Of course, the variance of the estimates for each strata will not be known until after the sampling has been completed, so in the absolute sense optimum sampling cannot be carried out. Nevertheless, assuming a Poisson distribution of fish densities the variances of ground fish catch rates in an area will be roughly proportional to the square of the density of fish.

The relative variances and a ranking of strata, based on other criteria, can be used to allocate the number of samples to each strata during the first cycle of sampling to achieve a result closer to that which would be achieved if sample sizes based on precise variances were used. In the second cycle, the actual variances observed can be used to estimate sample sizes. This procedure would tend to result in an adequate number of samples being taken in the small but important high-density strata, and at the same time ensure that a fair number of samples be taken in the larger less-dense strata. These less-dense areas, because of their larger size, may in total actually contain more fish (absolute numbers) than the other strata even though the fish may not occur in commercial concentrations. Therefore, the stock in these areas must be estimated if the overall potential yields (most of which would come from the best fishing areas) are not to be underestimated.

One way to allocate the samples, taking the expected variances into consideration, is illustrated in the following example:

(a) Suppose five strata have been determined in the survey area, and that a subjective estimate of the relative densities has been assigned as they were in the example of section 4.3.1:

Stratum number	Relative density
1	Very high
2	High
3	Medium
4	Low
5	Very low

Each of the five strata can be assigned a relative weight, based initially on subjective estimates of the relative variances. For instance, the stratum weights could be any of those shown in Table 4.3.2.

(b) For purposes of continuing the illustration, assume as is usually the case, that the survey must carry out sampling for a variety of biological and physical estimates. For some purposes of the sampling such as charting bottom types or taking physical oceanographic measurements stratified sampling proportional to area likely would be most efficient.[3] On the other hand, for estimating fish densities and potential yields, optimum sampling based on the variation of fish density (and not on the variation of the other factors being measured) is the most efficient.

[3] Assuming that some form of stratified sampling rather than systematic sampling is under consideration.

Table 4.3.2. Illustration of stratum weights

Stratum Number	Set 1		Set 2		Set 3		Set 4	
	Weight	Relative weight	Weight	Relative weight	Weight	Weight	Weight	Relative weight
1	16	0.516	12	0.500	8	0.421	5	0.333
2	8	0.258	6	0.250	5	0.263	4	0.267
3	4	0.129	3	0.125	3	0.158	3	0.200
4	2	0.065	2	0.083	2	0.105	2	0.133
5	1	0.032	1	0.042	1	0.053	1	0.067
TOTAL	31	1.000	24	1.000	19	1.000	15	1.000

When a number of estimates must be made, some of which are not correlated with fish density, the overall efficiency of the survey would best be served by a mixture of proportional and optimal allocation. The allocation of samples to the strata can be computed by using the following formula to compute sample sizes for each stratum:

$$n_h = n Pa_h Po_h \Big/ \sum Pa_h Po_h$$

Where n_h is the number of samples in stratum h, n is the total number of samples to be taken, Pa_h is the relative size of stratum h (Item (3)), and Po_h is the relative weight of the stratum based on the expected variation (Section (5) (a), Table 4.3.2).

An example of the calculation of sample sizes for a hypothetical situation is shown in Table 4.3.3.

Table 4.3.3. Total number of samples to be taken = n = 1000

Stratum	Stratum number	Area mi^2	Relative size of strata Pa_h	Relative variation (set 1) Po_h	$Pa_h \cdot Po_h$	$\frac{Pa_h Po_h}{\Sigma Pa_h Po_h}$	Sample sizes n_h
Highest density	1	25	0.014	0.516	0.0072	0.082	82
High density	2	180	0.103	0.258	0.0266	0.302	302
Medium density	3	360	0.206	0.129	0.0266	0.302	302
Low density	4	325	0.186	0.065	0.0121	0.137	137
Very low density	5	860	0.491	0.032	0.0157	0.178	178
TOTAL		1750	1.000	1.000	0.0882		1001 *

* The sample size of any stratum should be reduced by one to conform to the 1000 sample limit or alternatively allow 1001 samples.

4.3.4 Drawing the samples: the cruise track and sampling stations

In previous sections we have seen how to:

(1) Stratify the area (sections 4.3 and 4.3.1).

(2) Calculate the number of samples to be taken in each stratum (section 4.3.3).

(3) Select sampling sites at random (section 4.3.1, item 7).

Once these tasks have been completed and the locations of the sampling sites have been charted (presumably on a navigational chart), the investigator must decide which track the vessel will follow in its visits to each of the sampling sites. There is no intrinsic requirement of stratified random sampling that would dictate that the randomly selected stations be visited in the order they are drawn. This simple fact is related here because it is commonly misunderstood. However, if a time element such as season of the year (as well as other criteria) is used for stratifying the population, then naturally sampling sites selected for a particular time frame must be visited during the proper time - not before - not after. Normally, however, the sampling sites chosen for the cruise can be visited in whatever order is convenient. Persons interested in navigation will find the problem of minimizing the total distance traveled between stations an interesting one, but other considerations such as nearness to port at nightfall may also come into play.

5. ORGANIZATION OF FIELD WORK

In even small resource surveys many organizational problems will arise: personnel must be hired, trained, and supervised; equipment must be specified and ordered; and reporting and checking procedures must be established. In this section several procedures are discussed which will help the administrator organize and control the survey efficiently.

5.1 Network planning

Most projects will be planned using the technique of network analyses sometimes referred to as the Project Evaluation and Review Technique or PERT. The network will show the logical connection and sequence of the activities and events of the project. The network will help the Project Manager and his staff to develop the sequence of operations needed to fulfill the projects' objectives. During the early stages a network draft will serve as a useful frame of reference for discussions concerning the overall direction and planning of the project. In later drafts a network will be useful for the documentation and communication of project procedures. It will serve as a basis for training personnel in the purposes and objectives of the project and for showing each person how his activities fit into the overall context of the project. Still later, when the survey is underway, the network - revised and updated - will aid the project supervisors to exercise control by enabling them to easily recognize which activities are to be initiated, stopped, speeded up or slowed down.

5.2 Training and instruction - field operations manual

Experience has shown that the chances of success are improved if as far as possible everyone associated with the project understands the objectives and purposes of the survey and how his work fits into the overall plan. The network plan mentioned in the previous section is a helpful tool for this purpose. Aside from this training, the FAO and counterpart personnel must be given training in the standard operating procedures to be used on the survey. The instructions for taking the samples, measuring, recording, and reporting should be set out in a field manual. The manual should specify the person responsible for each activity to be performed on the cruise.

Prior to each cruise a briefing should be held. The vessel captain, officers, electronic technicians, and the entire scientific party should be present. Even with highly experienced personnel, it was observed that have found that even routine procedures must be reviewed to avoid serious errors. Changes to be made to the standard operating procedure and manual operations should be highlighted. A checklist of the subjects to be covered during the pre-cruise briefing session follows:

General cruise plan

(1) Objectives of the cruise

  (a) objectives that are to receive the highest priority or emphasis;

  (b) objectives which should be fulfilled if time or conditions permit.

(2) Date and time of sailing and return

(3) Cruise track and sampling sites (stations)

(4) Radio communication schedule and frequencies.

Operations of officers and crew

(1) Review the gear and rigging specifications and technique of fishing

(2) Review responsibilities for data recording and changes to forms or instructions

(3) Review the general requirements of the sampling design, the stratum boundaries and criteria for establishing stratum boundaries, particularly as they relate to navigation and locating the sample sites.

(4) Individual assignments and watch schedules

(5) Weather reports, safety and emergency measures.

Operations by scientific personnel

(1) Review procedures for handling fish catches: sorting, weighing, sub-sampling, and the deposition of catches and samples

(2) Review the data to be collected, the data recording forms, and other records to be kept

(3) Individual assignments and schedules.

The project should draw up a check-list of supplies and equipment that will be required for the cruise. The scientific personnel should be responsible for providing or checking the supplies of these materials before sailing time.

Checking the standard fishing gear is of special importance. It is often very easy to allow undesirable or "temporary" modifications of the fishing gear to remain because of lack of spare net sections or parts, or because of personnel changes. Prior to each cruise the person in charge of maintaining the gear and the survey director should compare the fishing gear with the standard specifications. This detail is important because interpretation of the results will be made with the standard net or gear specifications in mind. If, in fact, the gear configuration is different than the specification, serious errors may result in interpreting the sample results or in judging the usefulness of other gears.

5.3 Early checking of sampling procedures

A system should be devised early in the survey for checking the performance of the persons recording the data. Serious omissions or errors in the sampling techniques if corrected early will have minimal effect on the results. Data from the first cruise must be edited, processed, and checked for their accuracy before any serious deficiencies in sampling systems become standard procedure. The sampling scheme, including the sampling instructions should be reviewed constantly and changed when necessary.

5.4 Data recording forms

The forms required for recording the results of sampling and other field operations should be designed:

(1) For the convenience and accuracy of recording data in the field.

(2) To eliminate the need for data transcription before preparing summaries by hand or keypunching.

(3) To facilitate editing, coding, sorting, and arithmetic calculations.

A procedure for designing and using data recording forms for the survey follows:

(1) Prepare a list of all the data items required for the survey; include all essential data items.

(2) If data processing machines or computers are to be used to analyze the results, seek the the advice of a data processing professional when the list of data items is completed.

(3) Decide who will be responsible for recording each datum at a station. For instance, will the positions, depths, etc. be recorded by the skipper in the wheelhouse, while a biologist or technician on the stern, records the catch information on a separate form; or will all the data be recorded by a single individual?

(4) Decide how many different forms will be needed for the convenience of recording and which variables will appear on separate forms. The station number must appear on each separate form for identification.

(5) Print the units under the spaces provided for the data, or print the codes of possible outcomes to be circles or checked.

(6) Test the forms under field conditions and change them if they are not suitable.

5.4.1 An example of standard data recording form for demersal resource surveys

A standard form for recording the results of a trawl sampling operation is given in Figure 5.4.1. The data set out on this form represent the minimum set of information that is required from a trawl sample at a station.

The form is laid out to facilitate both data recording and keypunching. The design in this sense, is a result of a compromise between the requirements of the two tasks. If proper attention is paid to writing legibly and to editing the data, the information should not require transcription before it is punched.

Most of the items on the form are self explanatory, however, a few of the more esoteric ones need explanation.

Ser No. refers to the serial number of the gear. A code that is referenced to a drawing of the gears features and measurements. This item would be used especially during cruises that are using and evaluating various gears or gear modifications of the same general type.

Station Selec. is a space reserved for indicating the station selection procedure. During cruises in which the sampling or fishing station is selected for any one of several reasons the reason must be indicated so serious errors in the way the data are analyzed can be avoided. For instance, catches at stations selected for their concentrations of fish as indicated by sonar during the cruise and not selected randomly before the cruise could add a serious bias to the estimation of fish in the area if this fact was not taken into consideration during analysis. The station, such as the one described, is not representative; nevertheless, the data collected at these non-randomly selected stations could be useful for other purposes e.g., gear testing.

D or S merely refers to drifting or set nets or lines.

Biological data is a space reserved for marking a code to indicate that biological data were taken on the species or for a cross reference number to the biological data forms.

The spaces allotted for species names and codes are to be used for the up-to-twenty important species designated by the project. To facilitate data recording, the species names and codes can be stamped or printed on the form in an established sequence before the cruise.

FAO/UNDP PROJECT: FISHERY RESOURCE SURVEY FORM-MULTIGEAR

PROJECT	VESSEL	CRUISE No	DATE Yr Mo Day	SEQ No.	GENERAL LOCATION	

	SER No	STRATUM No.	DEPTH WATER	LOCATION	STATION SELEC.	DEPTH FLOATLINE	D or S	LENGTH OF NET		TIME SET	TIME HAUL	DURATION
GILL NET			m			m						h/min

	SER No	STRATUM No	DEPTH WATER	LOCATION	STATION SELEC	DEPTH GEAR	D or S	TYPE OF BAIT	SIZE HOOKS	No HOOKS	TIME SET	TIME HAUL	DURATION
LONGLINE			m			m							h/min

	SER No	STRATUM No	DEPTH WATER	LOCATION	STATION SELEC.			TYPE OF BAIT	No TRAPS		TIME SET	TIME HAUL	DURATION
TRAPS			m										h/min

	SER No	STRATUM No	DEPTH WATER	LOCATION	STATION SELEC	DEPTH GEAR		WIRE OUT	PERFORMANCE	CODE	TIME SET	TIME HAUL	DURATION
TRAWL HAUL 1			m					m					h/min

	SER No	STRATUM No	DEPTH WATER	LOCATION	STATION SELEC	DEPTH GEAR		WIRE OUT	PERFORMANCE	CODE	TIME SET	TIME HAUL	DURATION
TRAWL HAUL 2			m					m					h/min

	SER No	STRATUM No	DEPTH WATER	LOCATION	STATION SELEC.	DEPTH GEAR		WIRE OUT	PERFORMANCE	CODE	TIME SET	TIME HAUL	DURATION
TRAWL HAUL 3			m					m					h/min

	SER No	STRATUM No	DEPTH WATER	LOCATION	STATION SELEC	DEPTH GEAR		WIRE OUT	PERFORMANCE	CODE	TIME SET	TIME HAUL	DURATION
TRAWL HAUL 4			m					m					h/min

CATCH IN KILOGRAMS

SPECIES OR SPP GROUP	CODE	GILL NET A	LONGLINE B	TRAPS C	TRAWL 1 D	TRAWL 2 E	TRAWL 3 F	TRAWL 4 G	BIOLOGICAL DATA
TOTAL FISH									
TOTAL MOLLUSKS									
TOTAL CRUSTACEANS									

REMARKS : DESCRIBE WEATHER AND SEA CONDITIONS IF ADVERSELY AFFECTING OPERATIONS :

SEA TEMP SURFACE °C

FAO FISHERY DATA CENTRE, ROME

Figure 5.4.1 Example of data recording form for resource surveys.

6. METHODS OF MEASUREMENT

6.1 Measurement of the catch

The catch of any fishing operation for which the gear has performed properly must be recorded (including those with zero catches).

As a minimum requirement, the total live-weight catches (measured in kilograms) of fish, molluscs and crustaceans must be reported separately. Beyond that, depending on the objectives of the survey, many additional measurements from each catch may be required. Examples of these measurements are:

(1) Total live-weight catch of individual species or species groups.

(2) Total live-weight catch of market-sized fish.

(3) Total weight of fish discarded at sea.

(4) Total dressed-weight of fish (fillets, shrimp tails, etc.) kept for sale.

(5) Total weight of a sample of fish selected for length measurements.

Experience has shown that a great deal of confusion can arise concerning the definitions of various divisions of the catch. Therefore, it is important that the investigator describes carefully what is included in - or excluded from - each category for which separate weights are required.

The methods of estimating the catches from purse seine operations will usually differ from those of trawling, except for those occurrences when purse-seine catches contain a large number of species. The method of measuring the trawl catch is given in some detail in the following paragraphs.

6.1.1 Estimating trawl catches

It is recommended that projects conducting trawling operations determine the most important fish species (or closely allied species groups) for which live-weight catches will be reported in detail. Usually the number of species will be 10 or less. (Length frequencies should also be determined for these most important species.) A separate category "other fish" will include all other species. A less precise but adequate estimate of the catches of each species contained in the "other fish" category can be calculated from periodic samples for species composition by weight. Similarly, crustaceans and molluscs can each be divided into "important species" and "all others."

6.1.2 Sorted catches

Ideally the catch should first be sorted into standard-sized baskets or boxes by the designated species categories before the weight is calculated. If catches are consistently too large for the available manpower to perform this sort properly, consider taking shorter tows. If baskets of fish are to be selected for length composition samples, care should be taken not to sort the catch by size while the species sort is being carried out, unless the standard operating procedure calls for sub-sampling and subsequent analyses by size group.

The well-known tendency to select the larger fish first in the sorting process may cause a serious bias in the length frequency or age composition samples. This bias can be compensated for - if not eliminated - by requiring each worker sorting the fish to sort all the fish in an area of the pile before moving on to another area. This does not apply to very large fish such as sharks, large groupers, etc., which are usually counted or weighted individually.

After the catch has been sorted a record should be made of the number of evenly filled baskets of each group of fish. The weight of the catch is then calculated in kilograms by applying conversion factors of average weight per basket.

6.1.3 Unsorted catches

Very large catches composed of two or more species, need not be entirely sorted by species, especially if the manpower for the job is not adequate. In this case the very large specimens are first removed and weighed separately, while the remainder (roughly fish of the same size) are shovelled or scooped into the standard baskets. Enough baskets should be set aside and kept to provide a sample of about 150-200 kg of fish to calculate average weight per basket, species composition, and length frequency measurements.

The rest of the catch is disposed of after first counting the number of full standard-sized baskets and weighing the individual large fish species. The sample baskets of mixed fish are each weighed, an average weight per basket is calculated and is used to estimate the weight of the entire catch. Afterwards, the sample is sorted by species and the total weight in the sample of each species is determined. The percentage by weights of each species in the sample is then applied to the total weight of the catch to estimate the total weight of each species in the catch.

During the initial cruises several baskets of fish of each species should be weighed with a beam scale to establish the average number of kilograms of fish per standard basket for each species. The average weight of a standard volume will depend on the fishes' size, condition, shape and length of spines. Therefore, separate average weights of a basket of fish should be calculated for each species. It is unlikely that a single average weight would suffice for all groups or species of fish unless they have very similar characteristics.

In most cases it will be necessary to repeat the weighing process and calculate this average weight three or four times a year to determine if significant seasonal variations occur. If the average weight calculated from 12 baskets (three per station for four stations) is within plus or minus 5% of the previous season's estimate, a single average weight for conversion purposes will usually suffice. If the differences are greater than 5%, new average weights for the season should be used to preserve accuracy in the estimates.

6.1.4 Size of standard baskets or boxes

The standard baskets or boxes used for sorting and estimating the catch should hold approximately 20-25 kg of fish such as the hake. The baskets must be large enough to allow at least 25 normal-sized fish of the species usually caught to fit in the basket, and small enough to facilitate moving them by hand. An approximate guide to the number of various sized fish contained in a basket of roughly 35 litres in volume is shown below.

Average size of fish (cm)	Approximate number of fish in basket of 35 litres capacity
20	200+
30	100+
40	50
50	25

6.2 Measurement of fish lengths

The measurement of fish lengths for purposes of constructing a length frequency should be done according to the following standard rules and techniques:

(1) Fish species with stiff caudal fin rays that are likely to be broken or which cannot be easily bent into a straight line (mackerels, tunas and sharks) should be measured from the tip of the snout to the fork of the tail (fork length). Other species, with relatively soft caudal fin rays, will be measured from the tip of the snout to the tip of the tail with the lobes of the tail bent toward the median line of the fish, to bring the tail into maximum extension (total length).

(2) The straight line (horizontal) distance with the fish lying on its side should be measured instead of the contour around the body of the fish.

(3) Fish species with an average length normally below 20 cm will be measured in 1/2 cm intervals; species which average more than 20 cm in length are measured in 1 cm intervals.

(4) The number recorded for the length measurement shall be the lower boundary of the interval in which the tail of the fish lies. This means, for example, that the length of a fish which is larger than 24 cm but less than 25 cm will be recorded as 24 cm.

Therefore, it is to be understood that the mid-points of the length intervals recorded in whole centimeters will, in fact, be 1/2 cm larger than the recorded number, and the mid-point of the 1/2 cm intervals will be 1/4 cm larger than the recorded number. Tables 6.2.1 and 6.2.2 summarize the length recording convention.

Table 6.2.1. Intervals for fish averaging more than 20 cm in length

Actual interval	Number recorded to indicate interval	Mid-point of interval
≥ but <		
0 cm - 1 cm	0 cm	0.5 cm
1 - 2	1	1.5
2 - 3	2	2.5
. - .	.	.
. - .	.	.
. - .	.	.
15 - 16	15	15.5
16 - 17	16	16.5
17 - 18	17	17.5
etc. - etc.	etc.	etc.

Table 6.2.2. Intervals for fish averaging less than 20 cm in length

Actual interval	Number recorded to indicate interval	Mid-point of interval
≥ but <		
0 cm - 0.5 cm	0 cm	0.25 cm
0.5 - 1.0	0.5	9.75
1.0 - 1.5	1.0	1.25
. - .	.	.
. - .	.	.
. - .	.	.
10.0 - 10.5	10.0	10.25
10.5 - 11.0	10.5	10.75
11.0 - 11.5	11.0	11.25
etc. - etc.	etc.	etc.

Measuring boards or calipers constructed for length frequency measurements may have the numerals offset for ease of reading and recording. However, experience has shown that people tend to forget this fact and will use a board so constructed for exact measurements without compensating for the offset interval.

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APPENDIX I

INSTRUCTIONS FOR COMPLETING THE FAO FISHERY RESOURCE SURVEY FORMS

1. PURPOSE AND GENERAL DESCRIPTION OF THE FORM

The form is intended to facilitate and standardize the analysis and reporting of data collected by demersal resource surveys conducted with trawls. It can be used to present most of the salient facts concerning the stock size and first estimates of potential yields for the species or groups of species encountered during a survey. It also provides space for recording information about the amount of biological sampling conducted in each stratum during the survey and for recording length frequencies.

The form is divided into seven sections:

(1) Identification of the country, project, vessel, species or group of fish, general location of survey, period of time, and the fishing gear used.

(2) The average trawling conditions of speed, duration and area swept by the net and average area swept by the net in one hour of fishing.

(3) Summary of catch and effort data and catch per hour fishing in each stratum.

(4) Estimates of standing stock in each stratum and the total area assuming the gear to be 100% efficient.

(5) Biological sampling record for recording the number of specimens examined for length, age, maturity, etc.

(6) Length frequency of the species.

(7) Estimates of standing stock and potential yields under various assumptions of natural mortality rates and coefficients of gear efficiency.

1.1 Use of the form

Several features of the survey must be considered before a judgement is made on what data to include in the analysis or in interpreting the results. The usefulness of the form and the reliability of the data for these stock assessment calculations depend on the manner in which the survey was conducted. The manner in which trawling (sampling) sites are selected within the strata is of primary importance in judging whether or not the data should be included in the analysis. It is recommended that the standing stocks and potential yields be calculated using this form only when the locations of trawling sites are essentially determined at random.

As a practical matter some small biases may be tolerated, such as those that may be introduced by selecting an alternative trawling site when the randomly selected site is over untrawlable ground. The biases thus introduced will be minor if the relative area of untrawlable ground in the stratum is small or if the area of untrawlable ground is known and subtracted from the total area of the stratum before the calculations proceed.

Many more considerations must be made in interpreting the results of the analysis. The standing stocks that are calculated for the species or group of species will refer to the average standing stocks of the sizes caught by the gear and which were in the area during the time period of the survey. The accuracy of potential yield estimates calculated from these standing stocks must be interpreted in the light of judgements or information concerning: (1) limitations of the survey, (2) fish behavior, or (3) existing fisheries. Some of the features of the survey that may limit accuracy are such factors as the inability of the vessel(s) to cover the entire range of the stock, the efficiency of the gear in capturing the fish, or the accuracy in calculating area swept by the net. Similarly fish behavior in relation to the survey practices such as migrations into or out of the area will influence the accuracy of results. Finally, the theory on which the potential yield calculations are based assumes that the standing stock used in the calculation is not exploited by a fishery. If a fishery exists the mortality it already exerts on the stock must be evaluated before a final judgement on the potential yields is made.

2. COMPLETING THE FORM

A separate form should be completed for all species combined and for each important species each time all of the strata under consideration have been sampled. For example, if the total area under consideration is surveyed three times a year, a separate form for each important species and the total of all species would be prepared for each of the three cycles.

Separate forms for the species should also be completed for each type of trawl net used during the survey.

Definitions and procedures for completing each column or section of the form follows:

2.1 Country, project, vessel

Identify the country, project and vessel conducting the survey.

2.2 Species or group of species

Enter the scientific and common names of the species for which data are given. If genus and species have not been determined enter the family name, or otherwise indicate the groups of fish to which the data refer.

2.3 General location of survey area

Enter a concise description of the area in which the survey took place; boundary lines may be given by the latitude-longitude, e.g., Southeastern Gulf of Thailand, 5° to 10° N, 102° to 107° E.

2.4 Average haul

The average conditions of speed, duration and area swept should be indicated. The averages are based on the sum of the quantities for all the hauls divided by the number of hauls. The area swept by the average haul can be determined by multiplying the average speed by average duration to determine length of haul and then multiplying this quantity by a factor representing the "effective width" of the haul. In some cases, the "effective width" will be the distance between the otter boards while in others it may be the distance between wing tips or length of footrope. The measurement used for effective width should also be indicated.

2.5 Average areas swept in one hour of fishing

Indicat the area swept by a haul of average speed during one hour of trawling. This figure will be used in subsequent calculations of standing stock.

2.6 Stratum identification

Enter the identification of each stratum sampled during the survey. If stratified sampling was conducted within, say, depth intervals or the data were stratified by depth interval after sampling, the depth intervals corresponding to the definition of strata should be indicated. On the other hand, if sampling was conducted within a grid system such as one based on latitude and longitude and no further stratification of the data was made after the data were collected, the grid numbers that were used for identification can be entered. A chart showing the boundaries of the strata should accompany the set of forms.

2.7 Stratum area

The area (square nautical miles) of each stratum should be given. The accuracy of the standing stock estimates, and hence potential yields, will depend upon an accurate calculation of the stratum area. The definition of what should constitute the stratum will depend upon a knowledge of the fishes' behavior, and the nature of the bottom. For example, when the area of a grid square is calculated, it is obvious that the area of islands should not be included; however, depending upon the species, area of rocks, reefs,

dense algae beds or other untrawlable areas, may or may not be included. The investigation must define what area is to be taken into consideration for the purpose of calculating standing stock for each species or groups of species.

2.8 Catch

For each stratum enter the sum of the catches in kilograms obtained from all the hauls taken in the stratum during the time period.

2.9 Effort

For each stratum enter the total number of hours fishing with the given fishing gear. The number of hours should include the total time of all hauls, whether or not the haul produced a catch of the species in question. The time of fishing operations may only be excluded if the trawl did not function properly or was so damaged that fish could not be caught or escaped after being caught.

2.10 Catch per hour - kilograms hour

Compute and record the catch per hour in each stratum. The catch per hour for the entire survey area is computed from the total catch and total hours.

2.11 Standing stock with q = 1.0 (metric tons)

Assuming the gear efficiency coefficient q to be 1.0 (i.e. 100% of the fish in the area swept by the net were caught), compute the estimated standing stock in metric tons for each stratum by:

> multiplying "catch-per-hour" in kilogrammes times the "stratum-area" divided by average area swept by the net in one hour and moving the decimal points three places to the left.

2.12 Average weight

The average weight of the fish in each stratum can be recorded for the purposes of comparisons among strata and for computing abundance in numbers. The abundance in turn will be used to statistically weight the length-frequency samples to arrive at an overall length-frequence in the survey area. The units for average weight should be indicated.

2.13 Number of fish

The number of fish in each stratum can be estimated by dividing the weight of the standing stock by the average weight.

3. ESTIMATES OF POTENTIAL YIELD

3.1 General discussion

Computations of the first estimates of potential yields under various assumptions of natural mortality rates and gear efficiency coefficients can be recorded on the form.

The method of estimating potential yeilds is based on the theory discussed by Gulland (1970), Beverton and Holt (1966), and by Alverson and Pereyra (1969). The method relates maximum yield to a fraction of the virgin biomass. The value of the fraction is a function of two ratios: (1) the ratio of the natural mortality rate M to the parameter of the von Bertalanffy growth equation K, and (2) the ratio of size at first capture to maximum size. The potential yeild equation is usually expressed as $Y_{max} = XMB$, where Y_{max} is the maximum yield, M the coefficient of natural mortality, B_0 the virgin biomass, and X a fraction of M. B. For the mortality rates, growth rates and sizes at first capture normally encountered, the fraction of M times the unfished biomass which gives the estimate of maximum yield is approximately 0.4.

3.2 Estimates of natural mortality coefficient M

Record the most reasonable limits of the natural mortality coefficient and the "best" estimate.

The choice of limits of the mortality coefficient can be based on inferences derived from the growth rate or maximum size, if not of the species in question then from another in the same family. It is reasonable to assume that mortality rates determined for the species in other areas outside the survey area would make good estimates.

Literature sources or the reasoning on which the mortality rates were selected should be written on the reverse of the form or contained in a separate report accompanying the set of forms.

3.3 Estimates of gear efficiency coefficient q

The gear efficiency coefficient represents the relative proportion of the fish that were in the area swept by the net that are actually caught. The coefficient is expected to vary somewhat by the species and the type of gear used.

Accurate estimations of the coefficient are difficult to obtain; therefore, space is allowed for recording "reasonable" estimates of the maximum and minimum of the coefficient and the "best" estimate.

3.4 Standing stock for each estimate of q

Revised estimates of total standing stock for the various assumptions of gear efficiency values are calculated by dividing the total standing stock, computed with $q = 1.0$, by the estimate of q.

3.5 Estimates of potential yield

For the various combinations of the estimates of natural mortality and gear efficiency compute the value of $\frac{.4M}{q}$; these values can be recorded on the form. The estimated potential yields corresponding to each combination of M and q are derived by multiplying $\frac{.4M}{q}$ times the standing stock computed with $q = 1$. See Section 1.1 for discussion regarding the interpretation of the potential yield estimates.

4. INVENTORY OF BIOLOGICAL SAMPLING

Record the number of specimens from each stratum that have been examined for length frequency, age, or maturity. An extra column is provided for recording the sample sizes of other data collection efforts such as those for length weight, stomach contents, etc.

5. COMBINED LENGTH FREQUENCY

The length frequency samples taken from the catches within each stratum should be combined to produce the average length composition of the standing stock during the time period. Both the absolute length frequency (numbers of fish at each length) and the relative frequency (percent at each length) should be given. This length frequency will be useful for showing in a general sense the likely sizes of fish to be encountered in the area with the gear used. It can be compared to other size compositions from adjacent areas to help form hypotheses on migration.

In most cases for the purposes of the length frequency presented here, it will suffice to combine length frequency samples from catches taken in the same strata without statistically weighting them by the numbers of fish in individual hauls. A simple addition of the numbers at each length in the individual length samples within a strata and then computing the percentage at each length will represent the average length composition for the stratum. However, to obtain the overall L-F it will be necessary to statistically weight these length compositions by the estimated number of fish in the stratum to obtain the average length composition over all strata. This can be done by computing the number of fish at each length within each stratum and then summing the number at each length over all the strata. The overall relative frequency can then be computed and plotted in the space provided.

It should be noted that when it is desired to investigate the differences in length compositions between the strata for different gears or methods of fishing, etc., it may be necessary to calculate appropriate raising factors for the samples within a stratum in order to arrive at a more precise estimate of the size composition within each stratum.

6. GENERAL DESCRIPTION OF TRAWL NET

Describe the type (name) of trawl used during the survey. The codend mesh size (stretched mesh) should be indicated in mm. The length of footrope and distance between otter boards while the trawl is operating should be recorded in meters. The vertical opening of the trawl in meters should also be recorded. Auxiliary equipment (e.g., tickler chains, rollers, chafing gear) should be recorded as well.

LITERATURE CITED

Alverson, D. L. and W. T. Pereyra, Demersal fish exploitations in the northeastern Pacific Ocean - 1969 an evaluation of exploratory fishing methods and analytical approaches to stock size and yield forecasts. J.Fish.Res.Board Can., 26(8):1985-2001

Beverton, R. J. H. and S.J. Holt, Manual of methods for fish stock assessment. Part 2. Tables of 1966 yield functions. FAO Fish.Tech.Pap., (38) Rev.1:67 p.

Gulland, J. A. (Comp.) (Ed.), The fish resources of the ocean. FAO Fish.Tech.Pap., (97):425 p. 1970 Revised edition published 1971, West Byfleet, Surrey, Fishing News (Books) Ltd., 255 p.

FAO FISHERY RESOURCE SURVEY FORM - STANDING STOCK AND POTENTIAL YIELD

SHEET No. ____ OF ____ SHEETS

COUNTRY	PROJECT CODE	PROJECT No.	VESSEL	SPECIES OR GROUP: SCIENTIFIC NAME	SPECIES OR GROUP: COMMON NAME	GENERAL LOCATION OF SURVEY AREA	DATES: START (YR / MO. / DAY)	DATES: END (YR / MO. / DAY)	AVERAGE HAUL: SPEED (KNOTS)	AVERAGE HAUL: TIME (HOURS)	AVERAGE HAUL: AVE. AREA SWEPT (SQ. MI.)	AVERAGE AREA SWEPT IN 1 HOUR OF FISHING (SQ. MI. = a)

① STRATUM IDENTIFICATION	STRATUM AREAS SQ. MI. (A_i)	CATCH Kg	EFFORT No. OF HOURS FISHING (h)	CATCH PER HOUR (Kg/h)	② STANDING STOCK WITH q = 1.0 $.001A_i/B \cdot Kg/h$ (METRIC TONS)	AVERAGE WEIGHT OF FISH UNIT ____	NUMBER OF FISH	NUMBER OF SPECIMENS EXAMINED FOR: LENGTH FREQ	AGE	MATURITY		COMBINED L-F WEIGHTED BY NUMBER OF FISH PER STRATUM: LENGTH GROUP (cm)	FREQ. No. FISH	REL. FREQ. %

NO: 11214

$$\begin{array}{r} 39 \\ +\ 9 \\ \hline 48 \end{array}$$